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DETERMINATION THE STRETCH BENDING LIMIT RATIO FOR SHEET METALS DURING THE STRETCH BENDING PROCESS

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ABSTRACT

Stretch bending process plays an important role for improving the formability of the sheet metal, thus the formability of sheet depends on many effecting parameters on stretch bending process such as sheet metals types, sheet thickness, forming temperature, mechanical properties, etc. Stretch bending process has two types of plastic deformation operations: stretch and bending operation which controls the forming deformation for sheet metal. Thus, stretch bending process of sheet metal is type of sheet metal operation.

In this research, the stretch bending limit ratio for ASTM1020, ASTM B209 and AA3004 sheets have been determined experimentally, and it compared with simulation analysis to show the formability for all sheets. In addition, the thickness sheet and anisotropic effects are used in experimental work to show the effect of these parameters in the stretch bending process. The results shown that the AA3103 sheet has highest stretch bending limit ratio, while the lowest limit ratio is in ASTM B209 sheet.

KEYWORDS: Stretch Bending Limit Ratio, Thickness Ratio & Formability

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Original Article

1. INTRODUCTION

Stretch bending process plays a significant role to improve the sheet metal operation this is because using two difference operations in the same process. It can be affected by many parameters such as strain hardening exponent, strength coefficient, thickness, and anisotropic ratio [1]. Manufacturing researchers have spent much effort to improve the formability of sheet metals during the stretch bending operation. Sheet metal engineers and academic researchers have spent much effort to show the behavior of sheet metal during stretch bending operation over the last decade. Many studies have been achieved to investigate on the formability of sheet metal during forming process this is because the limit of strains depending on formability of sheets.

The limit of forming sheet represented via forming limit curve for all sheets metals which are suggested by many researchers [2][3][4][5].

Friedman, et. al [6] had achieved the limit strain of formability of biaxial stretch forming path theoretically using three types of yield criteria in theoretical solution such as Hill48, Hill79, Hosford79. They concluded that there are some differences in forming limit of sheets. Dariani and etal [7] studied the effect of the index for Hill79 criterion on theoretical FLD and comparing with experimental FLD. They discovered that the theoretical FLD matched with experimental FLD via changing the index of equation. Banabic and et al [8] used BBC2000 criterion [9] to determine the limit of forming for aluminum alloy Al2008 sheet theoretically. They showed that the theoretical curve matched with experimental curve for RHS of FLD.

In 2005, they used three types of sheet metals to determine the limit of fracture theoretically during the stretch bending process. Also, they used four sizes of punch to determine the effect of punch size on the formability of aluminum sheet. They noted that the theoretical forming heights are in good agreement with experimental results [10]. Anas O. B [11] used two different yield criterions with M-K analysis to determine FLD theoretically for sandwich sheets and comparing with experimental results [12]. They concluded that the theoretical FLD matched with experimental FLD using barlat-lian1989 [13]. Hansjörg S., et al. (2012)[14] used different types of sheet metals to determine the factor of spring back for all sheets using DEFORM 3D software. They found that the austenitic stainless steel sheet has highest spring back than all sheets while the Al 2024 has the lowest comparing with all sheets. Ji He, et al (2013)[15] used M-K analysis in theoretical procedure to determine bending forming limit diagram for sheets using different bending ratio. In addition, they investigated the effect of bending ratio on stress-forming limit diagram. Vishwajeet R. etal (2018)[16] achieved the forming limit diagram for mild steel sheet using stretch forming process experimentally, they discovered that the major and minor strains under forming limit line represented the safe region of formability for mild steel sheet.

The aim of this research determines the limit of stretch bending ratio for all sheets (Steel ASTM 1020, Aluminum ASTM B209 and AA3004 sheets) during stretch bending process. Anisotropic ratio, thickness of sheets and strain hardening exponent are the best parameters which uses in stretch bending process.

2. EXPERIMENTAL PROCEDURE

2.1 Compositions of Sheets Metals

The chemical composition of ASTM B 209, ASTM 1020, and AA3004 sheets were shown in table 1, 2, and 3.

Table 1: Chemical Analysis of ASTM B209 Aluminum Sheet

Material	Ti%	Mg%	Si%	Mn%	Cu%	Fe%	Zn%	Cr%	Al%
ASTM B209	0.017	0.015	0.1	0.02	0.02	0.21	0.03	0.004	**Rem.**

Table 2: Chemical Analysis of ASTM 1020 Steel Sheet

Material	C%	P%	Mn%	S%	Si%	Mo%	Cr%	Cu%	Fe %
ASTM 1020	0.2	0.003	0.2	0.02	0.05	0.005	0.04	0.02	**Rem.**

Table 3: Chemical analysis of AA3004 Sheet

Material	Mn%	Mg%	Fe%	Si%	Cu%	Cr%	Ti%	Al%
AA3004	1.31	1.01	0.65	0.3	0.25	0.02	0.02	**Rem.**

2.2 Mechanical Properties for Sheet Metals

The mechanical properties for all sheets can be collected via tensile test experiment using dog bone specimens (ASTM-A370). Three types of sheets metals are used in this research to show the stretch bending limit ratio for all sheets.

The mechanical properties of all sheets were obtained from tensile test. The values of Strain Hardening exponent (n), Strain rate sensivity (m), Yield stress 0.2% offset (YS) and Strength coefficient (K) were used in the theoretical determination of stretch bending process, are shown in table 4.

Table 4: Mechanical Properties of Sheets

Material	Strain Hardening Exponent (n)	Strain Rate Sensivity (m)	Strength Coefficient (K)[MPa]	0.2% Proof Stress [MPa]
ASTM B209	0.212	0.001	280	82.42
ASTM 1020	0.254	0.018	940	410.33
AA3004	0.315	0.0001	565.2	165.23

2.3 Stretch Bending Process

Stretch bending operation is one of the most important, fundamental and final processes in the sheet metal processes, it combines two operations in sheet metal process such as stretch and bending forming. The stretch bending limit ratio plays a significant role in stretch bending process, it used to determine the forming limit in sheet specimens during stretch bending process. In this process, a V-Punch, Die Holder and a Blank Holder are used to determine the forming limit during process, as shown in figure 1. The sheet metal holds inside die holder and then pressed via V-punch, the sheet metal has final shape look like punch head which represents stretch bending specimen.

Figure 1: Stretch Bending Equipment used in this Research.

V-punch (50mm in diameter) is used with dies and blank holder to complete the stretch bending process experimentally. Figure 2 shows sketch of the stretch bending equipment such as V-punch, blank holder, lower die and bolts. Figure 3 illustrates specific dimension of V-punch.

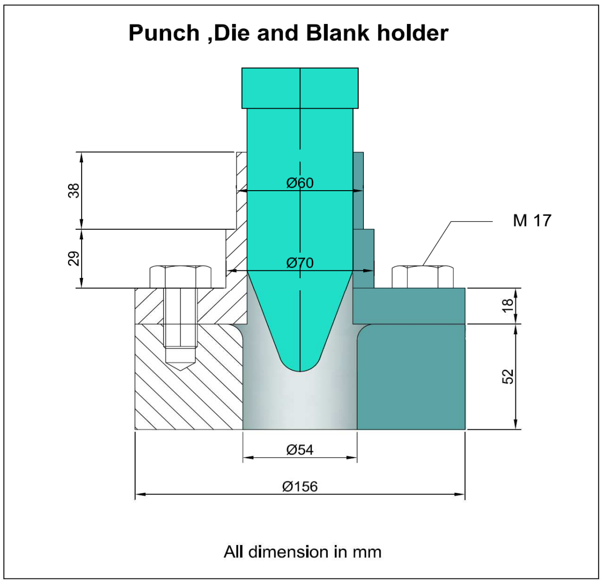

Figure 2: V-Punch, Blank Holder and Bottom Die.

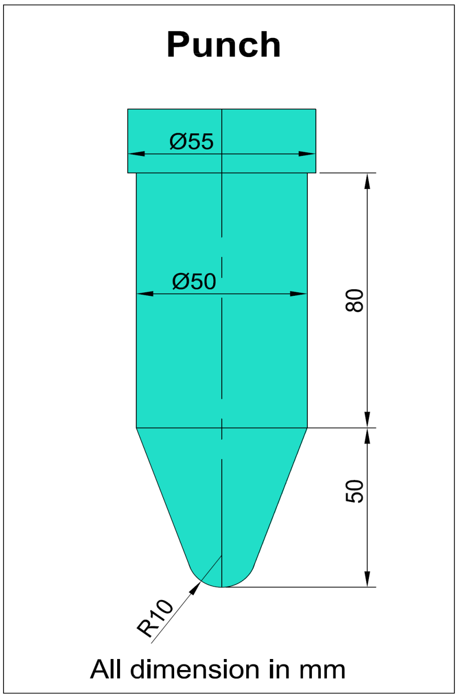

Figure 3: V-Punch used in Stretch Bending Process.

The stretch bending limit ratio represents the maximum length of deformation specimen to original length of specimen as shown in figure 4. In addition, the thickness ratio is another important parameter which represents sheet thickness to punch radius.

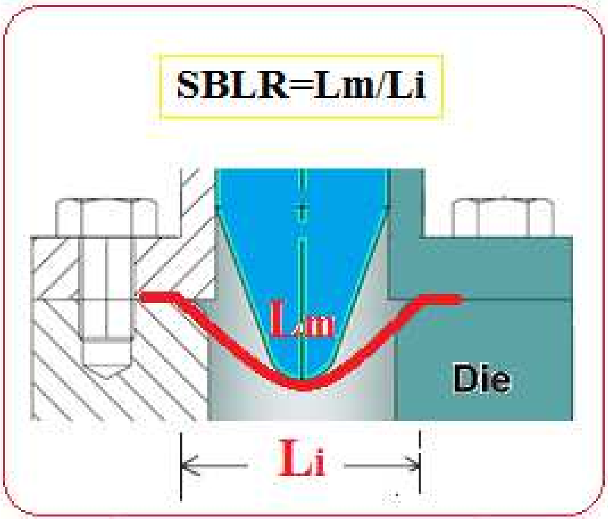

Figure 4: Stretch Bending Limit Ratio (SBLR).

3. THEORETICAL ANALYSIS

Theoretical analysis represents via finite element method using numerical software to determine limit stresses and strains in sheet metal during plastic deformation. Power law represents behavior of sheet metal during plastic deformation which is shown in equation 1

$$\sigma = K\varepsilon^{n} \tag{1}$$

Von_mises stresses are collected via numerical software, and it used to descript the stresses limits in the surface for sheet metal during plastic deformation of stretch bending process, which is shown in figure 5

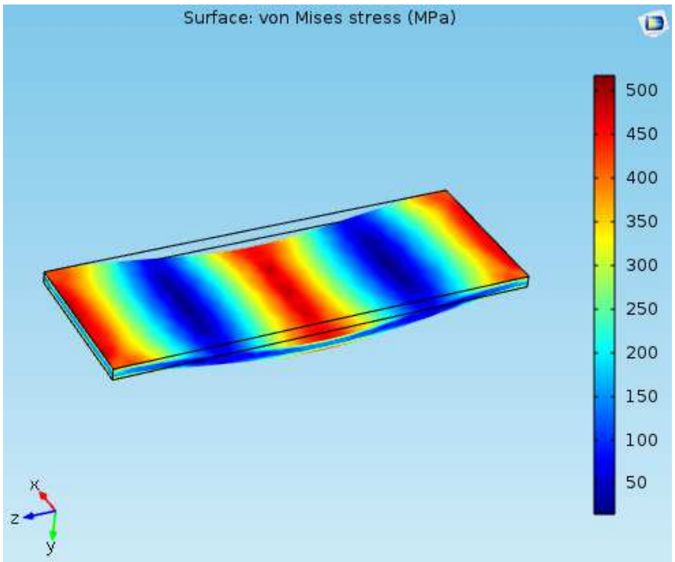

Figure 5: Von-Mises Stresses Analysis of ASTM B209 Sheet.

4. RESULTS AND DISCUSSIONS

The stretch bending process was experimentally determined and compared with theoretically results. The stretch bending limit ratio is the main factor to show the formability of sheet metals under stretch bending process. Figure 6 shows the stretch bending specimens after deformation for ASTM B209 sheets with difference angles of rolling direction.

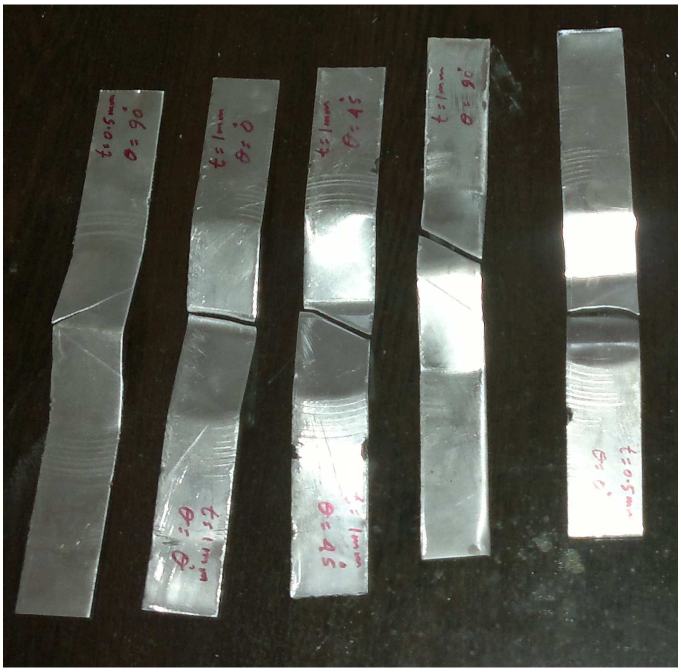

Figure 6: Stretch Bending Specimens after Deformation.

The forming depth during stretch benching depends on the types of sheet, and three types of sheets are used in this research. Figure 7 illustrates stretch bending limit ratio as a function of the forming depth for ASTM B209 sheet (1mm thickness) which is stretch bending specimen. Overall, it can be observed that the stretch bending ratio increases with

increasing forming depth. Also, the maximum stretch bending ratio in the last step of the stretch bending process is 1.051 at a forming depth 8.8 mm, while the minimum stretch bending ratio is 1 which starts point of the stretch bending process.

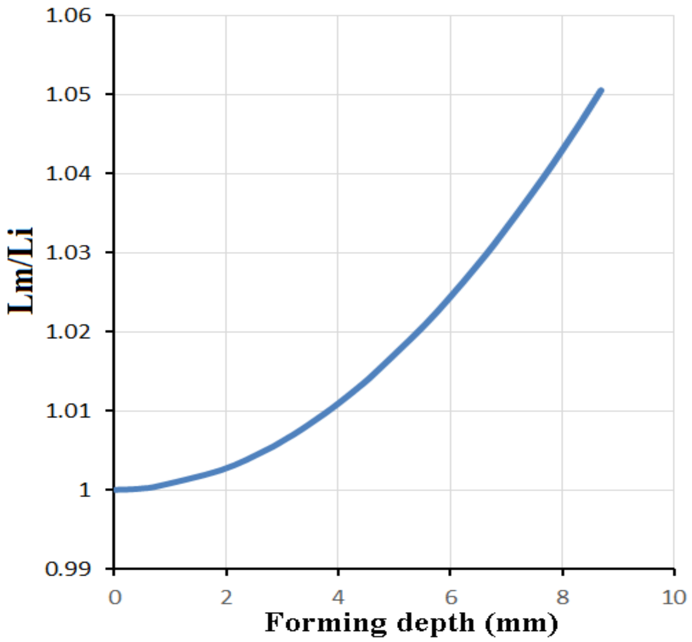

Figure 7: Stretch Bending Limit Ratio of ASTM B209 Sheet (1mm Thickness).

The influence of specimen direction on the stretch bending limit ratio for ASTM B209 sheet is shown in figure (8). It illustrates stretch bending limit ratio as a function of angles for specimen direction for ASTM B209 sheet (1mm thickness). Overall, it can be seen that the stretch bending ratio fluctuates with increasing angles of rolling. Also, the maximum stretch bending ratio in the last step of the stretch bending process is 1.0519 at a 0̊ while the minimum stretch bending ratio is 1.0409 at a 45̊.

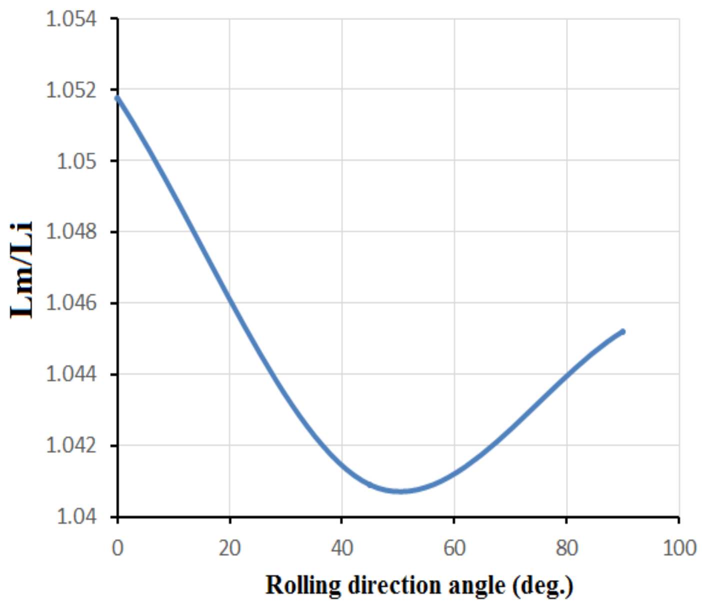

Figure 8: Stretch Bending Limit Ratio for Different Forming Angles (ASTM B209 at 1mm Thickness).

The impact of forming load on the stretch bending limit ratio for ASTM B209 sheet is shown in figure (9). It shows stretch bending limit ratio as a function of the forming load for ASTM B209 sheet (1mm thickness). Overall, it can be viewed that the stretch bending limit ratio increases with increasing forming load. Also, the maximum stretch bending ratio in the last step of the stretch bending process is 1.0519 at a forming load 1060N.

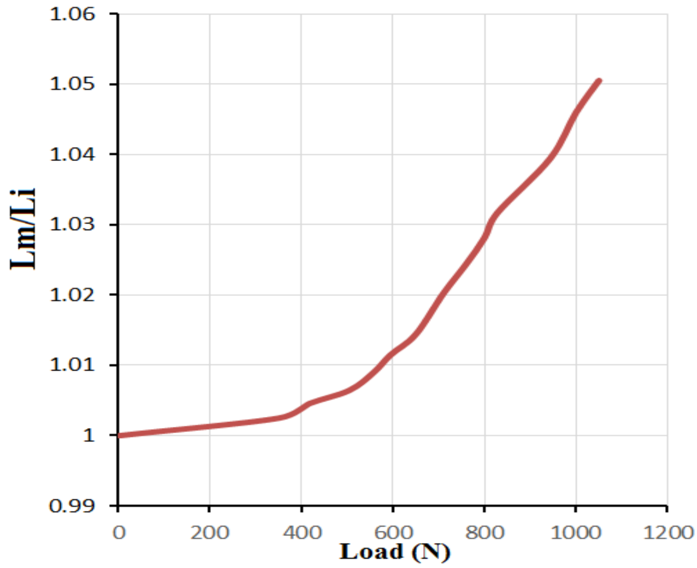

Figure 9: Stretch Bending Limit Ratio with Load Forming (ASTM B209 at 1mm Thickness).

Figure 10 illustrates maximum stretch bending limit ratio as a function of the thickness ratio for all sheet. Thickness ratio represents the thickness of sheet to radius of punch, and radius of punch is constant (10mm), thus thickness ratio changed via sheet thickness. Five sheet thickness (0.5–2.5) used in this research to show the effect of thickness ratio on the stretch bending limit ratio. Overall, it can be seen that the stretch bending ratio increases with increasing thickness ratio. Also, the maximum stretch bending limit ratio is 1.77 at a thickness ratio 0.25 of AA3004 while the minimum stretch bending limit ratio is 1.035 at a thickness ratio 0.05 of ASTM B209. Overall, it can be noted that the formability of AA3004 sheet is higher than other sheet.

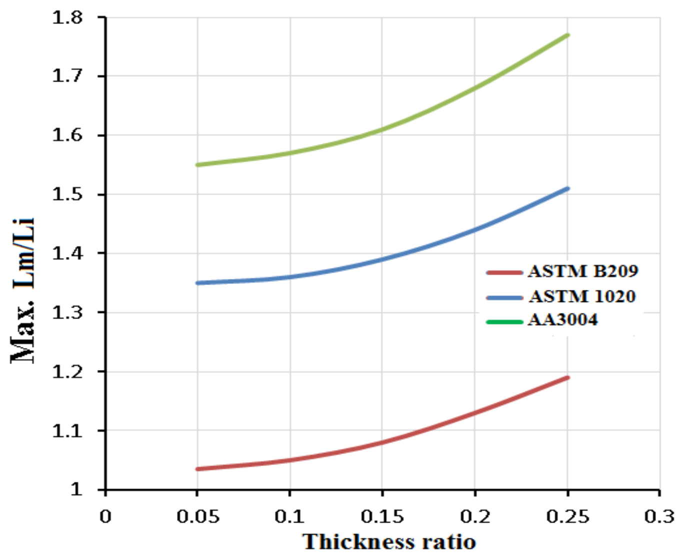

Figure 10: Maximum Stretch Bending Limit Ratio with Thickness Ratio for all Sheets.

Figure 11 illustrates the maximum stretch bending limit ratio for all sheets at thickness (1mm). The horizontal axis represents sheets types, while the vertical axis represents maximum stretch bending limit ratio. Overall, it can be noted that the maximum stretch bending limit ratio of AA3004 sheet is higher than all sheets, this is because the strain hardening exponent for AA3004 is higher than all sheets. Also, the maximum stretch bending ratio for AA3004 is 1.6372, while the maximum stretch bending ratios for ASTM 1020 and ASTM B209 sheets are 1.3629 & 1.0505 respectively which means that the formability of steel sheet more than the Aluminum sheet.

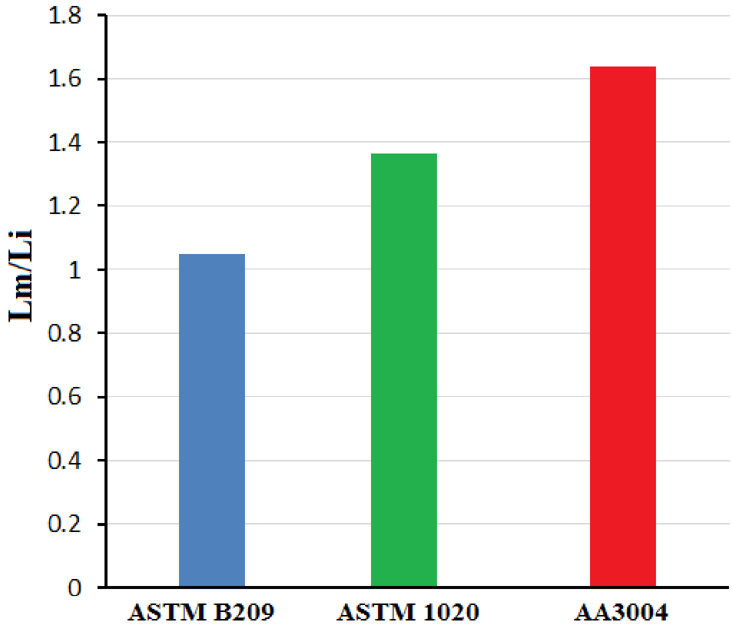

Figure 11: Stretch Bending Limit Ratio for all Sheets.

Figure 12 illustrates the forming depth for all sheets. Overall, it can be seen that the maximum forming depth of AA3004 sheet is higher than all sheets; this is because the formability for AA3004 is higher than all sheets. Also, the maximum forming depth of AA3004 is 36.3mm, while the maximum forming depth for ASTM 1020 and ASTM B209 sheets are 26.2 & 8.7mm respectively.

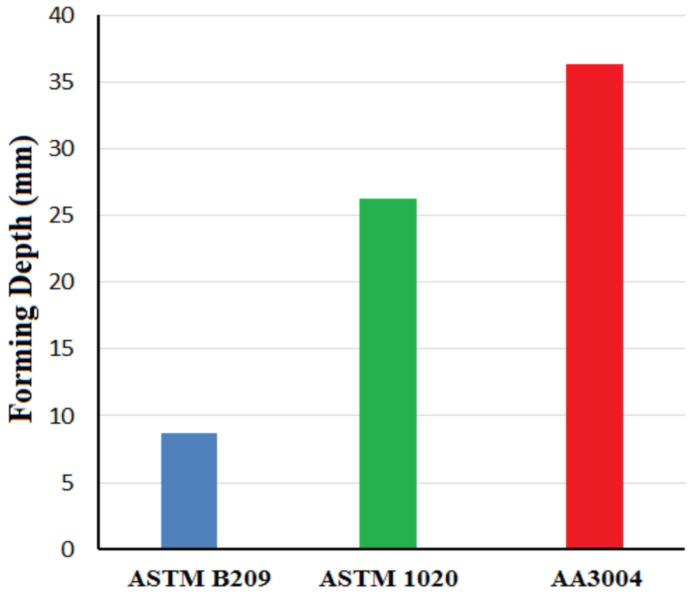

Figure 12: Forming Depth for all Sheets.

The impact of forming load on the stretch bending limit ratio for all sheets is shown in figure (13). It shows the stretch bending limit ratio as a function of the load forming for all sheets for (1mm thickness). Overall, it can be seen that the maximum stretch bending limit ratio of AA3004 sheet is higher than all sheets, while the load forming of AA3004 sheet is lower than steel sheets this is mean that the AA3004 sheet has excellence stretch bending properties comparing with another sheet. Also, the maximum forming load of ASTM1020 is 10.4KN, while the maximum forming load for AA3004 and ASTM B209 sheets are 6.4 & 1.05KN respectively.

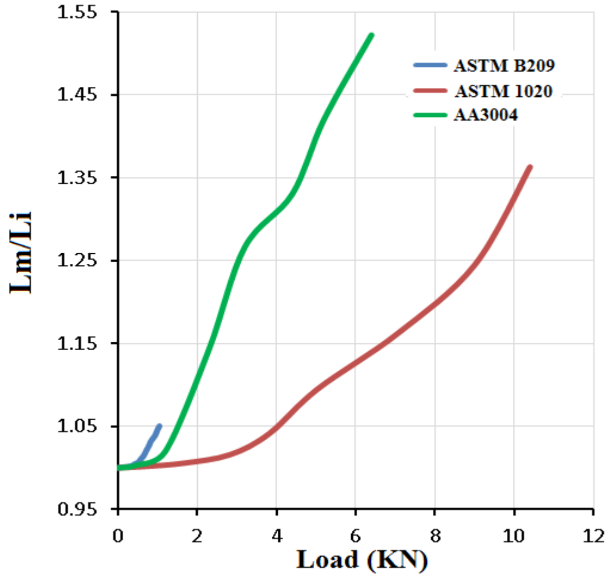

Figure 13: Stretch Bending Limit Ratio with Forming Load for all Sheets.

To determine the deformation depth and stress of specimen during operation, the stretch bending process was simulated via the commercial FEM software. The simulation results of total displacement for deformation specimen are shown in Figure (14). It illustrates the forming depth as a function of the specimen length for aluminum ASTM B209 sheet (1mm thickness) which is got from numerical solution. Overall, it can be considered that the maximum forming depth of ASTM B209 sheet is 8.5mm, and it compared with experimental forming depth as shown in figure (12), and concluded that the numerical results agree well with the experimental results.

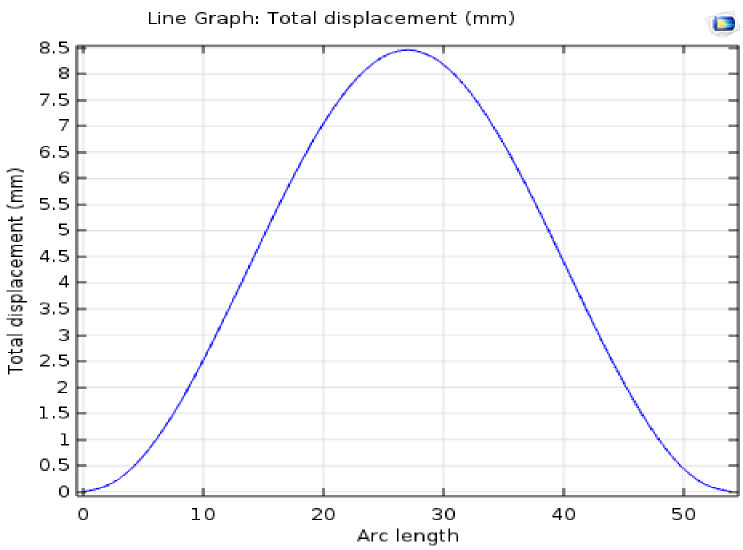

Figure 14: Forming Depth for ASTM B209 Sheet.

5. CONCLUSIONS

The main conclusions are recorded below:

- A good agreement between theoretical and experimental forming depth for all sheet.
- The formability of the AA3004sheet is higher than all sheets which are used.
- The stretch bending limit ratio is higher at 0 rolling direction compering with another direction.
- The ASTM 1020 sheet has high load than all sheet.

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